Validation of a dosimeter for the three-dimensional measurement of trunk motion

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INTRODUCTION

Back injuries still affect many workers. There is evidence that bending and twisting of the trunk and lifting at work are risk factors for back pain. Various methods are available for assessing bending and twisting of the trunk within a job. Recently, new types of instrumentation have been developed which combine different sensors. Backmann (2000) developed such a system consisting of a gyroscope, a magnetometer and a linear accelerometer. The data of each sensors are processed into a filter and produces orientation estimates. However, their system has not been validated exhaustively with human subjects. The purpose of this study was to evaluate a dosimeter composed of two sensors each including accelerometers, magnetometers and gyroscopes for the three-dimensional (3D) measurement of trunk motion.

METHODS

The instrument (dosimeter) consisted of two three-dimensional inertial tracking sensors (Micro Strain 3DM-G. Burlington) linked by a flexible rod with a potentiometer (figure 1). The two sensors were used to measure the orientation of the thorax relative to the pelvis. Each sensor comprised of three orthogonal gyroscopes which measured the angular rate of rotation, three orthogonal accelerometers which sensed the gravitational acceleration and three orthogonal magnetometers which are sensitive to earth magnetic field. The signals from the two sensors were transmitted to a computer (Casiopeia Five 230 MZ; Casio). The sample frequency was set to 76 Hz.

Figure 1. Illustration of the dosimeter

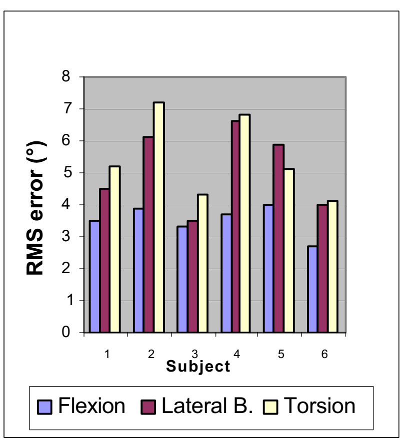

Figure 2. RMS errors during the long trial (30 min)

The data from the gyroscope were adjusted with the accelerometer and magnetometer estimates using a complementary filter [1]. The data of each sensors were processed into the filter which produced orientation estimates in quaternion form. These outputs were transformed into direction cosines where the three orthopaedic angles of Grood & Suntay [2] were computed: flexion-extension (angle α), lateral bending (angle β) and torsion (angle γ).

To validate the dosimeter, six male subjects were asked to perform manual handling tasks with empty boxes. They had to adopt different static postures (20) as well as to perform slow, moderate and fast lifts over a short period of time (30 sec) and, finally, to transfer boxes during 30 minutes. The task forced the subjects to exert large amplitude back motions. The dosimeter was tested by comparing the orientation as calculated by the complementary filter to the orientation that was obtained from a 3D optoelectronic system (Optotrak 3020 with four bars, Northern Digital Inc). The sensor orientation was obtained from six active markers attached securely to each sensor box. The root mean square difference (RMS) between the dosimeter and the Optotrak system was calculated for the three orthopaedic angles (α, β, γ)

RESULTS

Figure 2 illustrates the RMS errors for the three orthopaedic angles between the thorax and the pelvis during the long dynamic trials (30 minutes). RMS errors varied between 3 and 7° and were generally higher for the torsion angle (γ). Coefficient of multiple correlation was found to be higher than 0.90 for most of the long trials. Static and short dynamic trials resulted in smaller errors than the long trials, with the torsion angles having the highest level of errors (5°). Maximal errors were generally below 16° for the short trials. Speed of movement had a significant effect on the level of error but only in the order of 1 to 2°.

DISCUSSION AND CONCLUSION

Errors about the torsion angle (γ) can be explained by small disturbances from local magnetic field which affect the magnetic sensor. Gyroscopes also drift over time and the accelerometers used as inclinometer are influenced by quick motions. The filter worked well to overcome these sources of error, particularly during the long duration task. The results of this study indicates that the dosimeter is a valid system for the three-dimensional measurement of trunk motion. Future work should focus on obtaining more accurate data from long duration tasks .

REFERENCES

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2. Grood ES, et al. *J. Biomec. Eng* **105**, 136-144, 1983.

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